Research Note

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INFLAMMABILITY OF THE CURRENT YEAR'S LOGGING SLASH

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Logging slash usually constitutes a serious fire hazard in the northern Rocky Mountains. Forest protection agencies currently spend over a million dollars per year to abate the hazard. Knowledge of how slash inflammability varies in response to various factors is vital to effective, economical fire hazard reduction. Managers of slash disposal operations need information and techniques to determine where and how to concentrate their efforts, and when the hazard has been reduced to an acceptable standard.

In 1952 the Northern Rocky Mountain Forest and Range Experiment Station, cooperating with the University of Idaho, began a concentrated effort to get the answers to the slash inflammability problem. This report is the first fruit of the first year's research. To date the most significant finding is this: in dry, current year's slash, quantity of fuel is the prime factor affecting the rate of spread of fire. Apart from its relationship to quantity and arrangement of fuel, the effect of species is negligible.

The slash inflammability research project is in its infancy. The aim is to make an exhaustive study of the effects of species, quantity, and age of slash on inflammability. All nine commercial softwood species[1] of the northern Rocky Mountains will be included in amounts covering the full range of slash concentrations to be found after logging. Rate of spread is the chief manifestation of inflammability being studied at present. Other aspects of inflammability, such as ease of ignition and rate of drying, are examples of future subjects for study.

1/ Western white pine (Pinus monticola Dougl.), ponderosa pine (Pinus ponderosa Laws.), lodgepole pine (Pinus contorta var. latifolia Engelm.), western redcedar (Thuja plicata Donn), Douglas-fir (Pseudotsuga taxifolia var. glauca [Mayr] Sudw.), western larch (Larix occidentalis Nutt.), Engelmann spruce (Picea engelmanni Parry), grand fir (Abies grandis [Dougl.] Lindl.), western hemlock (Tsuga heterophylla [Raf.] Sarg.)

RESEARCH METHODS

The Slash Laboratory

Experimental burning of slash under controlled conditions is expected to be the biggest single job of the slash inflammability research program. To provide for the burning, an outdoor slash laboratory was established in May 1952 on the Priest River Experimental Forest in northern Idaho. A 5-acre flat was cleared of trees and fenced, and a weather station was built. Over 150 sample plots for experimental burning were established covering most of the area. Additional space was reserved for miscellaneous experimental layouts.

All commercial timber species of the northern Rocky Mountains are common in the Priest River area. Thus the desired species and quantities of slash can be cut near the laboratory and laid out for study. As soon as one burning schedule is completed, the plots are recharged with slash. The intention is to keep the plots continuously full of slash for some phase of the inflammability research program over the next 5 to 10 years.

Procurement and Preparation of Slash

Western white pine, western redcedar, Douglas-fir, and western hemlock were used in 1952. Slash was obtained from trees cut especially for the experiment. Live branches only from symmetrical, healthy trees were used. Most of the trees were in the 80- to 100-year age class; few branches were over two inches in diameter where they left the trunk. The fresh-cut slash was laid out on 48 0.01-acre plots fully exposed to the sun in the outdoor slash laboratory. The area was divided into four blocks, each having 12 plots. All four species were represented in each block at three concentrations: 7.5, 20, and 32.5 tons per acre, dry weight. Moisture content determinations on representative samples of each species provided the basis for calculating the corresponding weight of green slash to place on each plot. When the slash was weighed, equal numbers of branches from each third of the crowns were used. On each plot the slash was distributed as uniformly as possible.

The slash lay on the plots for six weeks during July and August. At the end of that time the material was judged to be about as dry as slash would ordinarily become during the year of its cutting. A little green and somewhat pliant material could be found in the bottom of the deepest concentrations, but the bulk of the needles and fine twigs appeared dry and could be crumbled in the hand.

Experimental Burning

At the end of the six weeks, three blocks, containing 36 plots, were burned, according to plan, during an extended period of dry weather. More than a week had elapsed since the last rain of 0.2 inch or more, and at least two days since the occurrence of any measurable precipitation. To avoid the effect of wind, the plots were burned after 4:30 p.m., when the average wind velocity was low. The rapid change in temperature and relative humidity characteristic of the evening transition period was accepted as a lesser evil than the erratic breezes of earlier hours.

Each plot was ignited exactly in the center by means of a pyrotechnic igniter fired by a blasting machine. Spread of the fire was measured along four diagonals marked off at 2-foot intervals from the center of the plot outward. Observers with stop watches recorded the time required for the fire to reach each successive 2-foot marker from the center out to 10 feet. Air temperature, relative humidity, and moisture content of $\frac{1}{2}$-inch sticks and basswood slats were recorded before each plot was burned, and at the end of each day's burning operations. Total wind movement was measured for the time during which each plot was burning.

Listed below are the extremes and averages of weather factors and fuel moisture content observed during the 1952 burning program:

Temperature: 48-82° F. (average 66° F.)
Relative humidity: 25-88% (average 54%)
Wind velocity: 0-2.4 mph[2/] (average 1.0 mph)
$\frac{1}{2}$-inch stick moisture content: 6.3-9.7% (average 7.9%)
Slash moisture content: 5.2-18.3% (average 9.4%)

Three to seven plots were burned each evening. The order of burning was staggered so that each plot being burned was surrounded by cool plots--either unburned or burned much earlier.

THE RESULTS AND THEIR SIGNIFICANCE

How the Field Measurements Were Handled

Preliminary examination showed that burning time plotted over distance from the plot center resulted in a straight line. Therefore linear regressions of time on distance were calculated to obtain average burning rate from the basic measurements.

The average time required per foot of radial spread was obtained from the regression lines for all plots in each species-weight combination. Burning time varied somewhat among plots of any one species-weight combination. Weather fluctuations during the tests appeared to be primarily responsible for variations in burning time. The effect of increasing relative humidity on rate of spread will be described in a subsequent research note. An attempt was made to put all plots on the same basis by applying a correction factor for weather conditions. Some reduction in variability was achieved but not a significant amount, and the correction was dropped until better data should be available.

2/ A wind of 4.1 mph occurred during an unsuccessful attempt to burn one plot of light hemlock slash.

Table 1 summarizes the results of experimental burning during 1952.

Table 1. Average number of seconds required per foot of radial fire spread on each plot and by species-weight combinations.

Weight of slash per acre	Burning time per foot of radial spread				Average time all species
	Western white pine	Western redcedar	Douglas-fir	Western hemlock	
	Time	Time	Time	Time	
	Seconds				
7.5 tons	90.5	74.5	56.3	No spread	
	68.7	44.0	58.8		
	87.9	115.7	128.0		
Average	82.5	68.8	74.6		75.6
20 tons	32.1	24.8	28.2	65.4	
	49.7	67.1	49.0	23.8	
	21.4	63.9	45.6	44.8	
Average	35.5	54.4	41.0	43.2	43.4
32.5 tons	14.2	21.6	15.8	15.4	
	18.4	27.7	23.8	20.7	
	19.3	23.2	22.8	52.3	
Average	17.6	24.2	20.8	28.5	23.0

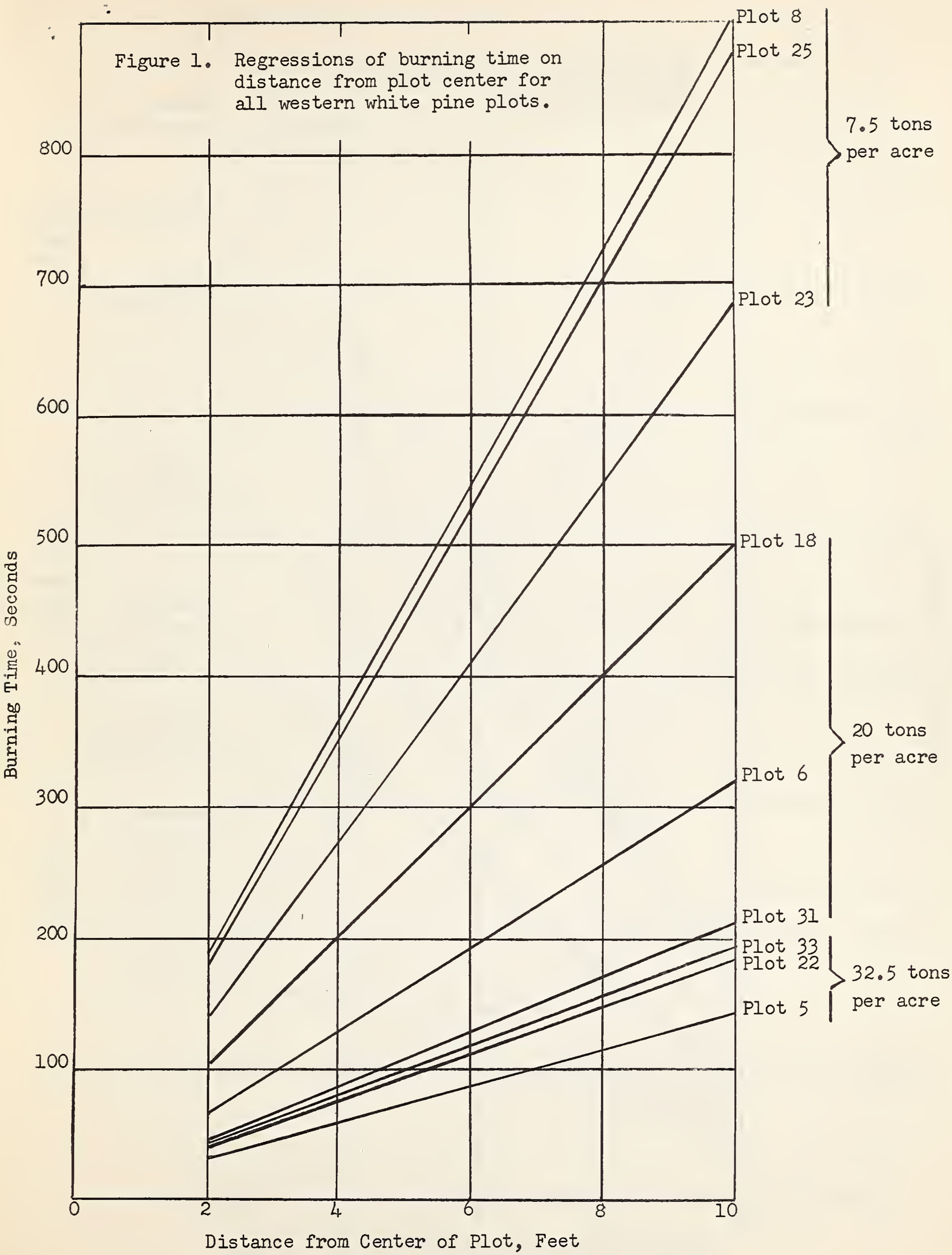
The Effect of Weight

Weight of slash per acre had a strong, consistent effect on rate of spread. Figure 1 shows how rates of spread on plots of western white pine were grouped by weight classes. The same general grouping prevailed in every species. Figure 2 includes generalized regressions for each species-weight combination. Again the regressions are clearly grouped by weight classes. Hemlock is not shown in the 7.5-tons-per-acre class because fires did not spread in the light hemlock slash. Rate of spread was more variable in light and medium slash concentrations because the effect of weather was more pronounced and the slash was somewhat less uniformly distributed than in the heaviest concentration.

Differences in rate of spread among weight classes were found to be highly significant statistically. A further statistical test[3] showed that the relationship between rate of spread and weight of slash per acre was curvilinear (figure 4) and could be expressed by the equation:
log (burning time) = 2.047 - .022 (weight per acre). Hemlock was not included in the preparation of figure 4 and the equation, but it appears that the same relationships would apply to hemlock slash in concentrations above about 12 tons per acre.

3/ Snedecor, George W. Statistical methods. 4th edition, pp. 382-384. The Iowa State College Press. 1946.

Figure 1. Regressions of burning time on distance from plot center for all western white pine plots.



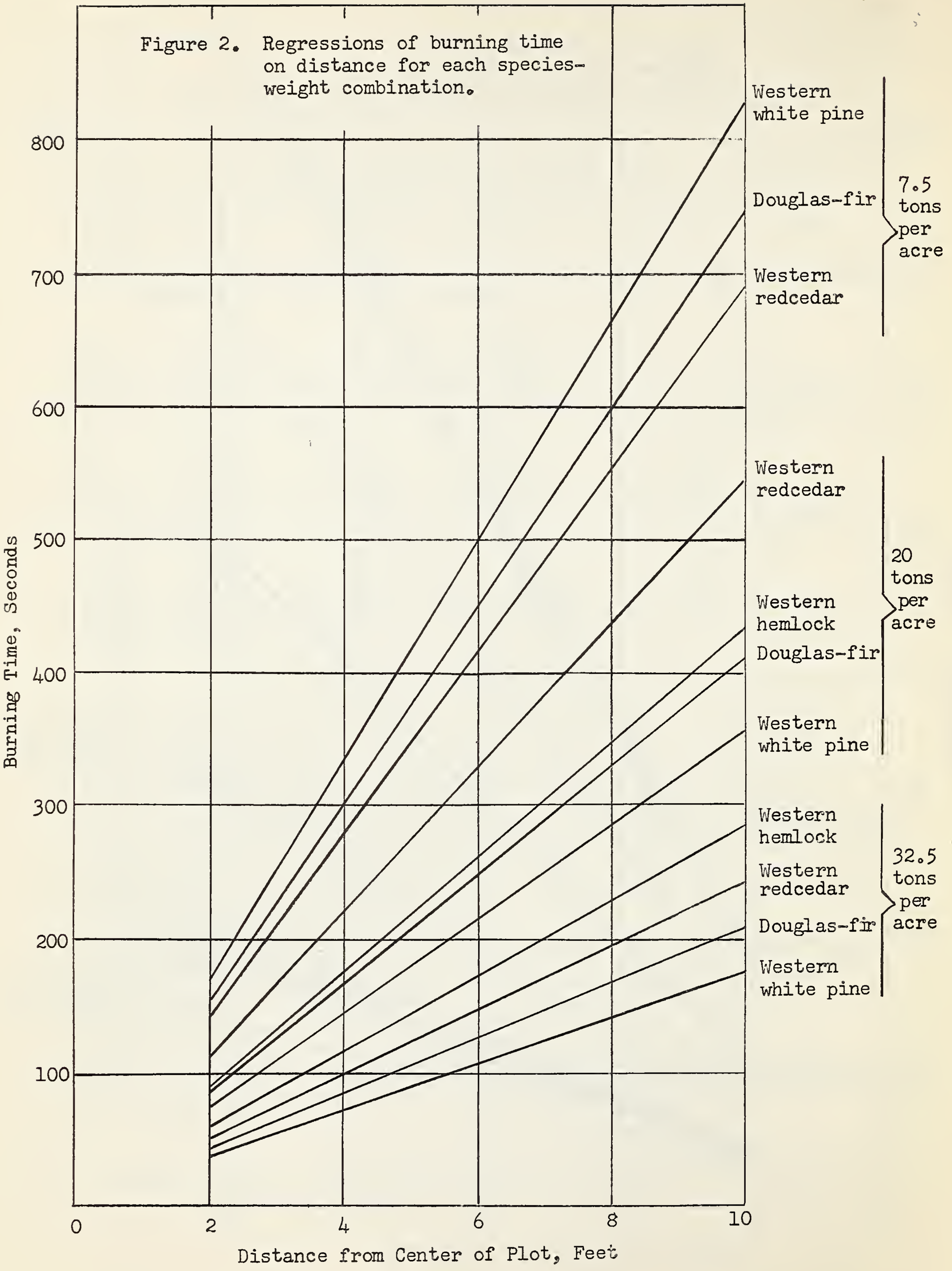


Figure 2. Regressions of burning time on distance for each species-weight combination.

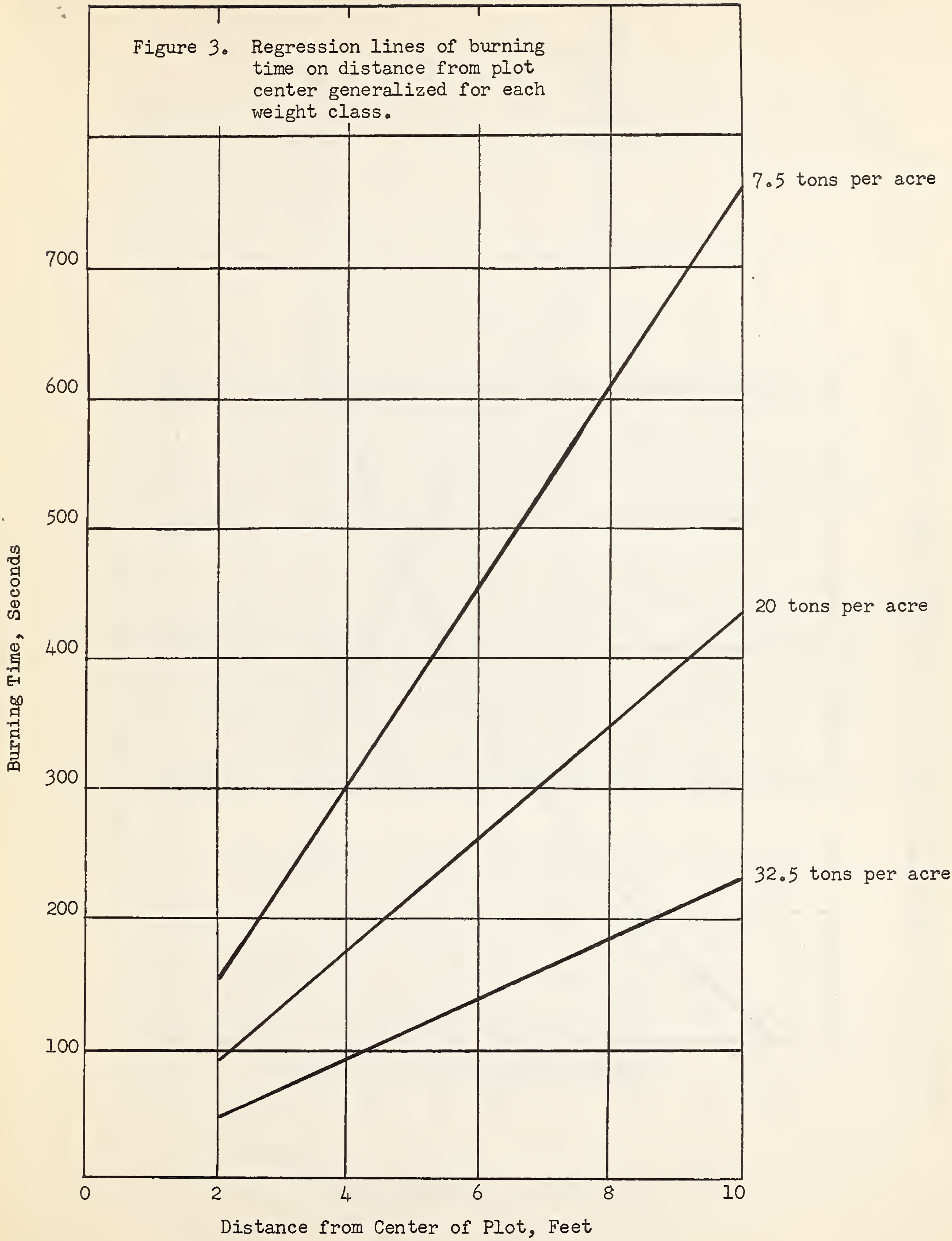
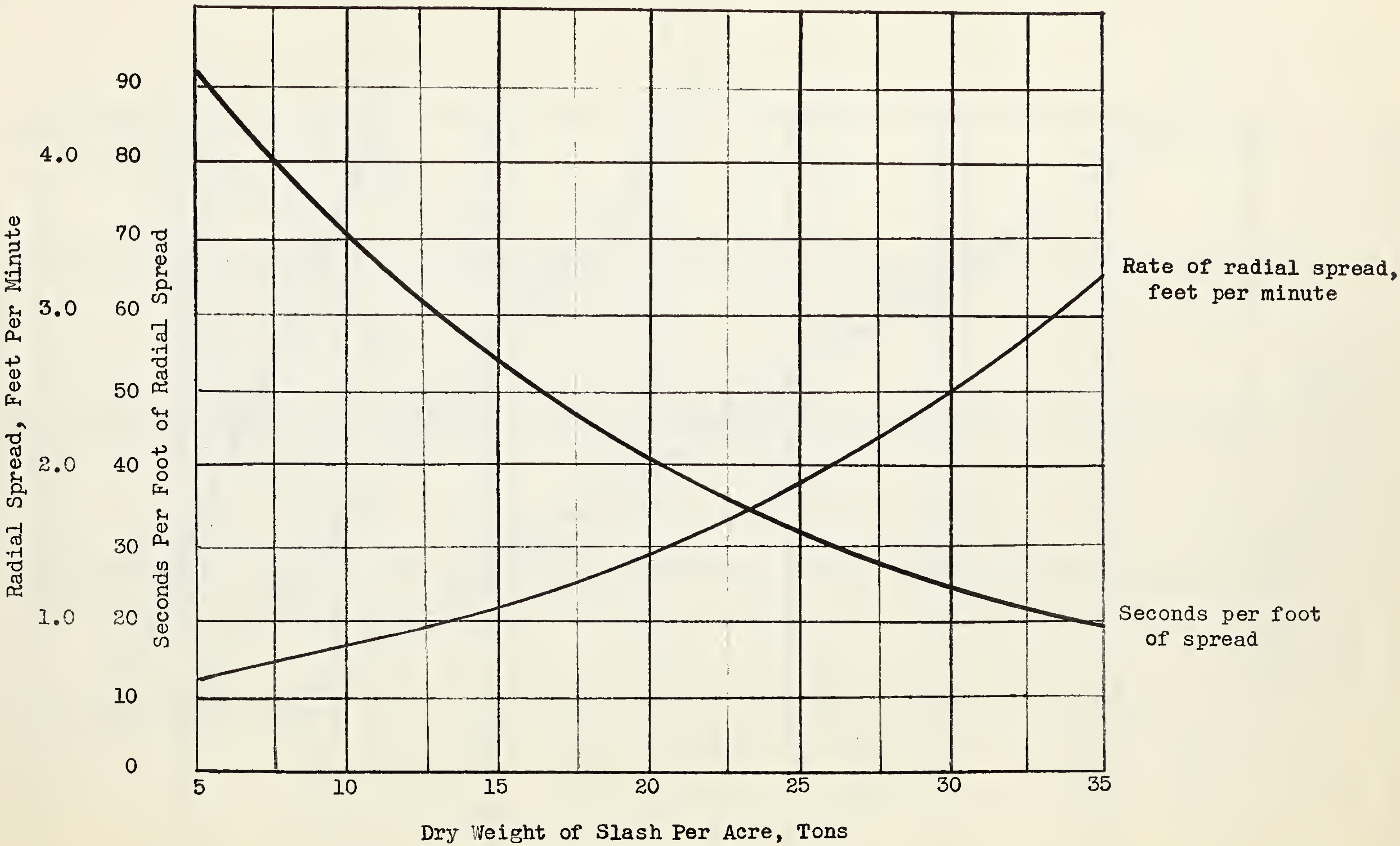


Figure 3. Regression lines of burning time on distance from plot center generalized for each weight class.

Figure 4. Relation of rate of spread to weight of slash per acre in current year's slash of white pine, cedar, and Douglas-fir.



The Effect of Species

Species had no appreciable effect on rate of spread beyond the failure of fires to spread at all in light hemlock slash, a species which loses its needles. Absence of needles from hemlock slash in heavier concentrations, however, did not result in slower fire spread than in slash of species which retained their needles. In figure 2 the relative positions of the four species vary from weight class to weight class. The implication is that species is not a uniformly important factor governing rate of spread. Statistical analysis showed that species had no significant effect on rate of spread in 20- and 32.5-ton-per-acre slash concentrations.

DISCUSSION AND CONCLUSIONS

Experimental burning of slash plots during the summer of 1952 has shed new light on fire behavior in logging slash and, to some extent, in fuels generally. Work with four common species of slash has shown rather clearly that, if quantity and arrangement are equal, only very great variation in physical characteristics produces significant differences in rate of spread. Furthermore, increasing the quantity of fuel may completely eliminate the effect of a factor which is very significant in light fuel concentrations. Thus absence of needles may have a highly significant effect in light slash but none at all in heavy slash.

Results of the study so far appear not to be in accord with the commonly held opinion, based on experience, that certain species of slash produce a much more serious fire hazard than others. Western redcedar is most frequently listed as the most dangerous species from the slash standpoint. During the 1952 experimental burning program, however, cedar exhibited no particularly explosive characteristics and was really below average in rate of spread. Western white pine exhibited the most violent burning activity. Observers formed the impression that fires spread fastest in white pine slash, but analysis failed to demonstrate any significant difference due to species. Even hemlock proved to be as inflammable as cedar, pound for pound, when present in sufficient quantity to offset the absence of needles.

The apparent disagreement between research findings and experienced opinion concerning the effect of species on inflammability will be further resolved when the results of investigations now underway are published. In the meantime the general statement may be made that weight is the key to differences among species in the case of current year's slash. Species commonly rated highly inflammable have large, heavy crowns with persistent needles and usually make up a large proportion of the stand if they are present at all. Those rated at the low end of the scale have small crowns, lose their needles after being cut, or occur relatively infrequently in the stand. Studies of quantity of slash per tree and per thousand board feet being carried on by the University of Idaho will clarify the relative inflammability of the various species.

Research done in 1952 has shed new light on the exact relationship between amount of fuel and inflammability. For the data obtained it was possible to express this relationship mathematically. The 1952 equations, however, are based on too few measurements of too few species and conditions to permit broad generalization. While a principle seems to have been discovered which will apply to all forest fuels, such broader application may not be attempted until more kinds and conditions of fuel have been investigated.